VIRTUAL ELECTROACOUSTIC AUDIOMETRY FOR UNAIDED, SIMULATED AIDED, AND AIDED HEARING EVALUATION

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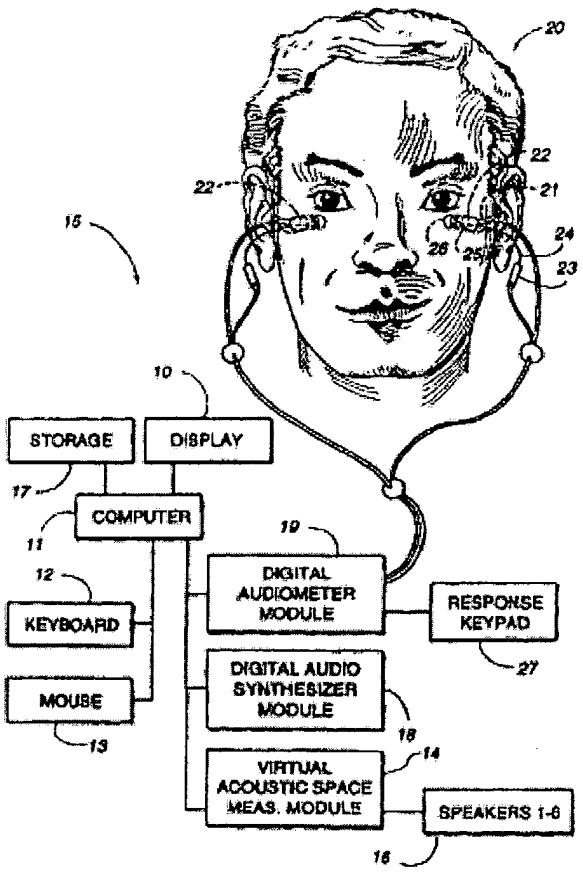
Abstract of corresponding document: **WO9723117**

Digital filtering (18) of one or more signal sources according to selected models and digitally controlled signal processing parameters, including audio sources, spatializing coordinates, acoustic boundaries, signals representing one or more simulated hearing aids, and individualized body/external ear transfer functions synthesizes a simulated three-dimensional acoustic condition for presentation to hearing-impaired person (20) for objective and subjective hearing evaluation via an intra-canal prosthesis (22) that is positioned in the ear canal (21), and that incorporates a microphone probe to measure in-the-ear-canal responses at a common reference point near the tympanic membrane (26) during unaided, simulated aided, and aided hearing evaluation. A virtual electroacoustic audiometer (19) computes the electroacoustic parameters of a hearing aid based on the results of the unaided audiometric evaluation and reference measurements that included the acoustic response near the tympanic membrane. The system then synthesizes acoustic signals reflecting the combined selection of audio signal model, spatialization model, acoustic boundaries model, as well as computed hearing aid model in the case of simulated aided condition.



VIRTUAL ELECTROACOUSTIC AUDIOMETRY FOR UNAIDED, SIMULATED AIDED, AND AIDED HEARING EVALUATION

Claims of corresponding document: **WO9723117**

CLAIMS

1. A system for assessment of the hearing function in humans, comprising:
a virtual electroacoustic audiometer for selective syntheses of acoustic signals for any of hearing diagnostics, hearing aid prescription, hearing aid simulation, and hearing aid fitting; and
an intracanal prostheses for delivering said acoustic signals and for measuring in-the-ear-canal acoustic response near the tympanic membrane during hearing evaluation.

2. The system of Claim 1, further comprising:
means for performing said assessment in terms representing absolute sound pressure level.

3. The system of Claim 1, further comprising:
means for performing hearing aid simulation by incorporating electroacoustic transfer functions into the digital synthesis of an acoustic signal.

4. The system of Claim 3, further comprising:
means for applying a hearing aid transfer function during syntheses of audio signals, including primary audio signals comprising pure tones and speech, and secondary audio signals comprising background noise and other competing sources.

5. The system of Claim 3, further comprising:
means for synthesizing audio signals, including primary audio signals comprising pure tones and speech, and secondary audio signals comprising background noise and other competing sources for hearing evaluation with any of a hearing aid and a simulated hearing aid.

6. The system of Claim 1, further comprising:
means for simulating any of a hearing aid occlusion effect, venting size, and oscillatory feedback potential.

7. The system of Claim 1, further comprising:
means for applying at least one transfer function to synthesize spatialized acoustic signals and create realistic listening environments in a multi-dimensional acoustic space.

8. The system of Claim 1, further comprising:
a digital audio synthesis module for generating an acoustic signal.

9. The system of Claim 1, further comprising:
a digital audiometer module for communicating acoustic information between said intracanal prostheses and said virtual electroacoustic audiometer.

10. The system of Claim 1, further comprising:
a virtual acoustic space measurement module for generating at least one acoustic transfer function to allow synthesis of spatialized acoustic signals.

11. A system for assessment of the hearing function in humans, comprising:
an intracanal prostheses for measuring in-the-ear-canal acoustic response near the tympanic membrane during hearing evaluation; and
a virtual electroacoustic audiometer for selective synthesis of acoustic signals representative of realistic listening environments in a multidimensional space for any of hearing diagnostics, hearing aid prescription, hearing aid simulation, and hearing aid fitting, said virtual electroacoustic audiometer including::
a digital audio synthesis module for generating an acoustic signal, including means for performing measurements in terms representing absolute sound pressure level;
means for performing hearing aid simulation by incorporating electroacoustic transfer functions into the digital synthesis of an acoustic signal;
a digital audiometer module for communicating acoustic information between said intracanal prostheses

and said virtual electroacoustic audiometer; and
a virtual acoustic space measurement module for generating at least one acoustic transfer function to allow synthesis of spatialized acoustic signals.

12. The system of Claim 11, further comprising:
means for performing hearing aid simulation by incorporating electroacoustic transfer functions into the digital synthesis of an acoustic signal.

13. The system of Claim 11, further comprising:
means for applying a hearing aid transfer function to synthesize audio signals, including primary audio signals comprising pure tones and speech, and secondary audio signals comprising background noise and other competing sources.

14. The system of Claim 11, further comprising:
means for simulating any of a hearing aid occlusion effect, venting size, and oscillatory feedback potential.

15. A system for assessment of the hearing function in humans, comprising:
a virtual electroacoustic audiometer for selective synthesis of acoustic signals representative of realistic listening environments in a multidimensional space for any of hearing diagnostics, hearing aid prescription, hearing aid simulation, and hearing aid fitting, said virtual electroacoustic audiometer including:
a digital audio synthesis module for generating an acoustic signal, including means for performing measurements in terms representing absolute sound pressure level;
means for performing hearing aid simulation by incorporating electroacoustic transfer functions into the digital synthesis of an acoustic signal;
a digital audiometer module for communicating acoustic information between said intracanat prostheses and said virtual electroacoustic audiometer; and
a virtual acoustic space measurement module for generating at least one acoustic transfer function to allow synthesis of spatialized acoustic signals.

16. The system of Claim 15, wherein said virtual acoustic space measurement module measures individualized transfer functions that include any of an individual's acoustic effects of body, head, external ear, and face plate on incoming acoustic signals from a multi-dimensional acoustic space.

1 7. A system for assessment of the hearing function in humans, comprising:
a virtual electroacoustic audiometer for selective syntheses of acoustic signals representative of realistic listening environments in a multidimensional space for hearing diagnostics, hearing aid prescription, hearing aid simulation, and hearing aid fitting; and
an intracanal prostheses for delivering such acoustic signals and for measuring in-the-ear-canal acoustic response near the tympanic membrane during hearing evaluation;
wherein said system provides simultaneous signal delivery and measurement within the ear canal near the tympanic membrane.

18. The system of claim 17, wherein said measurements are performed at a common reference point near the tympanic membrane during all phases of hearing aid fitting to directly correlate measurement data.

19. A method for selecting and presenting binaural acoustic stimuli in spatialized mode for hearing diagnostics and rehabilitation, comprising the steps of:
synthesizing audio signals, including primary audio signals comprising pure tones and speech, and secondary audio signals comprising background noise and other competing sources;
controlling spatialization parameters of said audio signals, including the position of each source in space in terms of any of distance, azimuth, and altitude; acoustic boundary parameters including room size, reflectionpropertles, reverberation, atmospheric absorption and spreading loss roll-off; and
presenting such spatialized stimuli to an individual.

20. The method of Claim 19, further comprising the step of:
presenting such spatialized stimuli to predict performance of one or more hearing aid systems.

21. The method of Claim 19, further comprising the step of:
presenting such spatialized stimuli for simulating a hearing aid system.

22. The method of Claim 19, further comprising the step of:
presenting such spatialized stimuli for hearing aid evaluation.

23. A method for in situ simulation of at least one hearing aid, comprising the steps of:
selectively simulating electroacoustic parameters of a hearing aid with a virtual electroacoustic audiometer, said electroacoustic parameters including:
a. signal processing parameters, including gain, frequency response, filtering, and signal adaptation to incoming sound; and
b. acoustic parameters, including venting effects, insertion depth effects, oscillatory feedback potential, and occlusion effects; and
simulating physical parameters of a hearing aid with an intracanal prostheses, said parameters including hearing aid size and comfort.

24. A method for assessment of the hearing function in humans comprising the steps of:
synthesizing acoustic signals for hearing diagnostics, hearing aid prescription, hearing aid simulation, and hearing aid fitting; and
delivering said acoustic signals and measuring in-the-ear-canal acoustic response near the tympanic membrane with an intracanal prostheses.

25. The method of Claim 24, further comprising the step of:
measuring in situ the occlusion effect due to the insertion of a simulated hearing aid.

26. The method of Claim 24, further comprising the step of:
fitting a hearing aid based on subjective response and in situ measured response to signal models that are spatialized according to spatialization parameters and according to an individual's transfer functions.

27. The method of Claim 24, further comprising the step of:
directly coupling acoustically said intracanal prostheses to a hearing aid microphone for hearing aid evaluation and in situ aided hearing evaluation.

28. The method of Claim 24, further comprising the step of:
predicting and simulating the occurrence of oscillatory feedback.

29. The method of Claim 28, wherein said predicting and simulating step incorporates a measured acoustic feedback transfer function.

30. The method of Claim 24, further comprising the step of:
providing hearing aid specifications based on simulated hearing aid characteristics that are interactively developed and optimized by synthesizing said acoustic signals, and by simultaneously measuring the acoustic response near the tympanic membrane.

31. The method of Claim 24, further comprising the step of:
selecting and specifying a hearing aid system which produces natural sound perception by matching in situ acoustic response characteristics of said hearing aid system to that of an unaided response in a multidimensional acoustic space.

32. The method of Claim 31, further comprising the step of:
testing said hearing aid in a synthesized realistic acoustic environment.

33. The method of Claim 24, further comprising the step of:
evaluating and optimizing an individual's ability to detect movement of sounds in a multi-dimensional space.

34. The method of Claim 24, further comprising the step of:
evaluating and optimizing an individual's ability to localize sounds in a multi-dimensional space.

35. The method of Claim 24, further comprising the steps of:
measuring acoustic response of an individual's own voice in an occluded ear canal via said intracanal prosthesis; and
subtracting an unoccluded ear canal reference measurement therefrom;
wherein an objective measure for occlusion effect is calculated.

36. A method for measuring the occlusion effect on either of a simulated hearing aid and a hearing aid, comprising the steps of:
measuring acoustic response of an individual's own voice in an occluded ear canal via either of said intracanal prosthesis or said hearing aid;

subtracting an unoccluded ear canal reference measurement therefrom, wherein an objective measure for occlusion effect is calculated; and
adjusting a calculated occlusion effect measurement by the difference in the spectral characteristics of an individual's own voice.

37. A process for fitting a hearing aid, comprising the steps of:
performing a reference measurement;
performing an unaided hearing evaluation;
performing a predicted aided evaluation;
performing a simulated aided evaluation; and
performing an aided evaluation.

38. A method for assessment of the hearing function in humans, comprising the step of:
providing audibility spectrogram plots that show on one plot the audibility of a particular acoustic signal according to critical features of the signal and a hearing profile of an individual.

39. The method of Claim 38, further comprising the step of:
interactively fitting either of a hearing aid and a simulated hearing aid by selecting, adjusting, and optimizing parameters on said hearing aid and/or said simulated hearing aid based on said audibility spectrogram.

40. A method for hearing assessment in an individual, comprising the step of:
directly coupling an acoustic signal to a hearing aid microphone for hearing aid evaluation and in situ aided hearing evaluation.
